

PATENT SPECIFICATION

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(54) CONSUMABLE ARC-WELDING ELECTRODES

(71) We, PREMIER INDUSTRIAL CORPORATION, of 4415, Euclid Avenue, Cleveland, Ohio, United States of America, a corporation organized and existing under the laws of the State of Ohio, United States of America do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to the field of metal joining, cladding and surfacing by fusion, generally referred to by the broad term "welding". More particularly, the invention relates to electric arc deposition welding and to the electrodes used in such welding.

Metal welding processes are so well known and widely used as to require no exhaustive description here. Welding is generally a fusion method or process in which the workpiece or substrate is at least partially melted and molten filler metal is deposited thereon. The filler metal may be of the same composition as the substrate or may be dissimilar in composition. Workpieces to be welded together may be of like composition or may be dissimilar to each other.

The foregoing metal arc fusion processes all utilize concentrated heat for elevating base metal temperatures and melting the filler metal. Other sources of heat, such as gas combustion, radiant energy and pressure-friction also are known for fusion joiner. However, electric arc welding is the technique most commonly used. The invention is directed to the consumable filler metal rods used as electrodes in arc welding.

For purposes of the present description, consumable filler metal electrodes may be steel, iron, or other ferrous alloy, nickel, nickel-base alloy, or non-ferrous metal such as aluminum, copper, or alloys thereof. Bare metal electrodes have a specialized and limited use. They are difficult to operate and to control, and weld metal quality often is poor. Consequently, electrodes commonly are covered with external coatings of suitable fluxing and/or deoxidizing compositions to improve

operation and weld deposit quality. Such coatings are applied by dipping the core in a liquid slurry or, more often, by concentric extrusion of a plastic mixture and baking the resultant coating. Sometimes, an electrode has a primary coating of one composition for a particular purpose and a second coating of another composition to serve another purpose. Disclosures of coated and double-coated electrodes appear in U. S. Patent Nos. 1,368,287; 1,669,660; 1,669,661; 1,931,466; 2,008,447 and 2,870,047 and are representative of the state of the art.

Most of the electrode coatings commonly used in the welding art have a granular, porous structure which is moisture absorbent even under ambient storage conditions. Absorbed moisture rapidly impairs the coating and its efficacy and may eventually result in an unusable electrode. Consequently, most coated electrodes have a relatively short shelf life and, when not used immediately, have progressively impaired performance and weld deposit characteristics.

The nature of arc welding is such that there are problem areas in which improvement in welding electrodes is desired and sought. Among these problems are the relatively high levels of electric current needed to maintain adequate arc temperatures and voltages; the inability of electrodes, particularly electrodes of relatively small diameter, to perform properly outside of a narrow range of current values; the overheating of electrodes with consequent loss of arc drive; the inability to make efficient use of AC in certain welding applications; and inadequate arc stability and weld bead control in out-of-position welding operations.

The invention is directed to improving the performance characteristics of welding electrodes by overcoming or minimizing some of the previously mentioned problems which exist in arc welding as well as to improving the shelf life of coated electrodes. Essentially, this is accomplished by sheathing a welding electrode in an energy-reflective continuum, the most common form of which is metal. This

provides a secondary coating for a coated electrode, and also may serve as a vapor barrier against the absorption of moisture into the primary flux coating.

5 The metallic sheathing which serves as an energy-reflective coating permits the use of lower and broader ranges of electric current values while maintaining higher arc voltages and higher arc temperatures at given amperage values. Arc stability is enhanced and arc drive is maintained for substantially optimum electrode performance over a greater length of the electrode consumed. The resulting improvement in penetration of the substrate and the stabilization of current values produces greater wetting action of the deposit, a flatter and cleaner bead with greater adherence to the substrate, easier start in striking the arc, and improved joints in vertical and other out-of-position welding. Improvements in operation and weld deposit quality are noted particularly with welding electrodes of relatively small diameter, such as those in which the diameter of the core is $\frac{1}{8}$ " or less. Operation on alternating current is enhanced. All the various types of welding electrodes to which this invention may be applied exhibit improved performance in one or more aspects which vary with such factors as electrode composition, electrode diameter, flux coating composition, arc current and voltage, substrate metal and the technique of welding employed.

According to the present invention there is provided a consumable arc-welding electrode, comprising, in combination, a consumable metal core, a modifier-containing coating on said core, and an adjacent sheath providing an energy-reflective continuum substantially surrounding said coating.

Also in accordance with the present invention there is provided a consumable arc-welding electrode, comprising, in combination, a consumable electro-conductive metal core, a primary coating on said core, and an adjacent sheath providing an energy-reflective continuum substantially surrounding said primary coating.

Further in accordance with the present invention there is provided a consumable arc-welding electrode, comprising, in combination, a consumable electro-conductive metal core, a modifier-containing primary coating adherent to said core, and a sheath adjacent to said primary coating and providing an energy-reflective continuum substantially surrounding said primary coating.

The present invention will be further illustrated, by way of example, with reference to the accompanying drawings in which:

60 Fig. 1 is a view in elevation of an arc welding electrode embodying the invention, a portion thereof being broken away to show its cross-section.

65 Fig. 2 is a transverse cross-sectional view, taken as indicated on line 2—2 of Fig. 1.

Fig. 3 is a photomicrograph, at a magnification of about 2X of a conventional arc-welded butt joint in a sheet steel substrate $\frac{3}{32}$ " thick.

Fig. 4 is a photomicrograph comparable to Fig. 3, but using a metallic sheathed electrode under like operating conditions.

Fig. 5 is a photomicrograph, at a magnification of about 2X, of two conventional arc welded deposits made on a cast iron plate at two different electrical current levels.

Fig. 6 is a photomicrograph comparable to Fig. 5, but using a metallic sheathed electrode under like operating conditions.

Fig. 7 is a photomicrograph, at a magnification of about 3X, of a conventional arc welded deposit made on an aluminum plate $\frac{1}{4}$ " thick using an aluminum welding electrode.

Fig. 8 is a photomicrograph comparable to Fig. 7, but using a metallic sheathed aluminum electrode under like operating conditions.

Fig. 9 is a photograph, enlarged about 2X, of a conventional fillet weld made between adjacent steel plates using a consumable arc welding electrode.

Fig. 10 is a photograph comparable to Fig. 9, but using a metallic sheathed electrode under like operating conditions.

Fig. 11 is a cross-sectional view similar to Fig. 2, but showing a modified form of the invention.

Fig. 12 is a graph showing values of moisture absorption for conventional flux-coated electrodes and the comparative values for metallic sheathed electrodes embodying the invention.

Figs. 1 and 2 show a representative form of sheathed electrode 10 having a metal core 11 of wire or rod and a circumferentially extending adherent primary coating 12 of a fluxing composition. Conventionally, the primary coating 12 extends and covers substantially the entire length of the core 11, except for a short terminal portion 13 which is left bare for electro-conductive contact with the electrode holder (not shown) used in electric arc welding. Circumferential to the flux coating 12 is a secondary coating in the form of an energy-reflective metallic continuum or sheath 14. The sheath 14 may have a variety of formulations and may be applied to the electrode by a variety of techniques.

Basically, the sheath 14 comprises an energy-reflective layer of non-ferrous metal or alloys thereof, a ferrous metal or alloys thereof, or mixtures thereof, which is deposited on or applied to the electrode as an adherent continuum. The metal may constitute 100% of the sheath or it may constitute only a portion of the composition of the sheath, the remainder being in the form of a suitable vehicle, binder or matrix for the metal continuum. Essentially, the minimum metal content of the metallic sheath is that which will provide a substantially continuous energy-

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reflective face or surface or continuum adjacent to the primary flux coating 12. In practice it has been found that it is desirable, to achieve an effective continuum, that the metal content of the sheath preferably be at least 10% by volume and not less than 5% by volume as a minimum in situ on the electrode.

The metal of the metallic sheath may be in the form of thin sheet, foil or film, or it may be in the form of a continuum of reflective particles, such as metal flake particles. Alternatively a film of a reflective metal having a low melting point may be applied in the molten condition to produce an adherent cast film upon subsequent cooling, or suitable films may be applied by deposition from the vapor phase as, for example, an evaporated film of reflective metal. The manner of application depends upon the physical state of the sheath 14 composition which is to be utilized.

The non-metallic portion, if any, of the sheath 14, is primarily intended as a vehicle for the metallic portion and may, for example, consist of one or more organic resins, inorganic binders or combinations thereof. However, the invention does not preclude the minor additions of other metallic or non-metallic ingredients having particular functions or desired characteristics, such as deoxidizers, for example, provided that such additions do not substantially reduce or diminish the reflective ability of the sheath.

The thickness of the sheath 14 may depend upon the field of use of the particular electrode involved. Although even an extremely thin continuous reflective film may be shown to have some beneficial effect on electrode performance and weld quality, in general it has been found that the wall thickness of the annular sheath should be at least .0001". The beneficial advantages of the sheath 14 do not appear to be enhanced when the thickness of the sheath is increased beyond about .005" although thicker sheaths may be operable. For most arc welding applications, the thickness of the sheath is preferably from .0005 to .003". Excessive thickness of the sheath is not only unnecessary and wasteful, but if carried to extremes, can be counter-productive and have a deleterious effect on weld deposit quality.

Although the described sheath is a metallic continuum with respect to its ability to serve as an energy-reflective coating surrounding the electrode, it is not necessary that the sheath be an electrical conductor. Preferably, electrical conductance of the sheath should be sufficiently small so as not to detract from the main stream of arc current carried by the core of filler metal 11. Owing to the minimal thickness and composition of the sheath, this generally will be the case.

Examples of sheathed welding electrodes embodying the invention and the improved results attained, are given below.

Example 1.

The electrode selected for test comprised a mild steel core wire 1/16" in diameter coated with a primary layer of heat-cured, inorganic deoxidizing flux compositions. Sample electrodes were sheathed by dipping in a liquid composition comprising aluminum flake particles and a silicone-modified alkyd resin in an organic solvent medium, then allowing to dry during which process the aluminum flake pigment leafed to form a reflective continuum about .002" in thickness as a resin-bonded sheath adherent to the primary flux coating. This sheath, when dry, comprised about 45% by volume of aluminum flake particles in the resin matrix. Both sheathed and comparison unsheathed electrodes were used to make welded butt joints between adjacent mild steel sheets 3/32" in thickness by means of a single, horizontal weld pass along the juncture. The current used was 45 amperes AC. Under these conditions, the conventional, unsheathed electrode produced a high-crowned bead at the juncture with only partial penetration of the juncture interface as seen in Fig. 3, whereas the sheathed electrode produced a substantially flatter, wider bead with complete penetration of the juncture and a solid weld joint, as shown in Fig. 4.

Example 2.

The electrode type selected for test and the conditions of sample electrode sheathing were similar to those of Example 1, the only significant difference being that, for this test, electrodes having cores of 1/8" diameter wire were used. Weld tests were performed using both sheathed and conventional unsheathed electrodes at a current of 90 amperes AC to make vertical-up fillet welds between 3/16" mild steel plates meeting at a juncture angle of 90°. In this test, the beneficial effect of the sheathing was pronounced; as compared to the unsheathed electrode under the same conditions, the sheathed electrode produced a much flatter, more uniform fillet weld joint and with a much better wetting of the substrate by the weld deposit as evidenced by a lower contact angle between the weld bead and the substrate.

Example 3.

The electrode type selected for test was similar to that of Example 2. Samples were dip-coated in a composition comprising equal parts by weight of aluminum flake particles, stainless steel flake particles and a coumarone-indene resin together with organic solvents. The thickness of the air-dried sheath layer was .003". Tests of comparative welding ability of sheathed and unsheathed electrodes were made using a welding current of 110 amperes DC reverse polarity (electrode positive) to deposit horizontal stringer beads on the surface

of a mild steel plate $\frac{1}{4}$ " thick. It was noted that, under the same welding conditions, the sheathed electrodes gave a much smoother operation and a flatter weld deposit, or bead. Better wetting of the substrate by the weld deposit was evidenced by the low contact angle between the edge of the weld bead and the surface of the substrate plate in the case of the weld deposited by the sheathed electrode.

Example 4.

The electrode type selected for test comprised a mild steel core wire of $\frac{3}{32}$ " diameter coated with a primary layer of a cellulosic flux composition. This type of electrode is widely used in welding practice for the joining of low-carbon steel members. Samples were coated with a leafed, reflective sheathing of aluminum flake particles in a silicone-modified alkyd resin matrix according to the practice described in Example 1. Welding tests were made by depositing horizontal stringer beads on $\frac{1}{4}$ " mild steel plate using a current of approximately 75 amperes AC. Under the same welding conditions, the sheathed electrodes appeared to offer the operator a better control of the weld deposit and a more stable arc current than the unsheathed electrode. The improved stability of the arc current was observed through the use of current measuring devices to meter the welding current in the conductor from welding generator to electrode holder and to verify a significant decrease in the range of fluctuation of welding current during the course of the welding operation.

Example 5.

The electrode type selected for test was similar to that of Example 2. Samples were coated with a slurry prepared by suspending 15% by weight of aluminum flake particles in a solution of inorganic binder material made by diluting 40° Beaume sodium silicate solution with water in about 1—1 ratio. For general tests of the reflective sheath effect, this mixture was simply brushed onto sample electrodes, allowed to air dry, and then the electrodes were baked at elevated temperatures to thoroughly dry the coating. For tests of out-of-position welding ability, the previously described slurry was further diluted with water to form a medium having the consistency of light cream into which sample electrodes were dipped, withdrawn, air-dried, and baked at 200°C for 12 hours. Thickness of the reflective sheath of aluminum flake particles in inorganic binder was .003". To further protect against moisture absorption, coated electrodes were given a light overcoating about .0003" thick, of a film consisting of 12% by volume of copper flake in an acrylic resin binder, and applied by spraying followed by air drying. The weld performance of both sheathed and

unsheathed electrodes was measured by making vertical-up fillet welds between $\frac{1}{4}$ " mild steel plates adjacent at 90°, using a welding current of 115 amperes AC. Under these conditions, the unsheathed control electrodes produced very high-crowned, round beads with poor wetting of the steel substrate plates whereas the sheathed electrodes produced excellent flat beads with good wetting of the substrate plates.

Example 6.

The electrode type selected for test was a nickel-base core wire $\frac{3}{16}$ " in diameter coated with primary flux composition containing graphite as an ingredient to control weld quality in the joining and repair of cast iron. To provide an energy-reflective sheath according to the invention, sample electrodes were tightly wrapped with a single layer of commercial aluminum foil .003" thick. Electrodes so sheathed were compared with conventional unsheathed electrodes by welding horizontal stringer beads on cast iron plates $\frac{3}{8}$ " thick using a welding current of 140 amperes DC reverse polarity (electrode positive). As compared with the unsheathed electrodes under the same conditions, the sheathed electrodes gave flatter weld deposits and better wetting of the substrate by the weld metal as evidenced by a lower contact angle between the weld bead and the substrate.

Example 7.

The electrode type selected for test was similar to that of Example 6 except that the diameter of the nickel-base core wire was $\frac{1}{8}$ ". Sample electrodes were sheathed by dipping in a mixture of aluminum flake particles and silicone resin (Dow-Corning #806A) in organic solvent medium, drying in air, and baking 12 hours at 220°C. to cure the silicone resin matrix. The cured sheath film comprised 67% aluminum flake by volume and was .002" thick. Sheathed electrodes were tested by making horizontal stringer beads on cast iron plates at a current of 105 amperes DC reverse polarity. The sheathed electrodes produced excellent weld beads, smooth, with good wetting of the substrate and no porosity in the weld bead. Similar results were observed in testing electrodes of the same type and manner of sheathing but having core wire diameters of $\frac{5}{32}$ " and $\frac{3}{16}$ ". At welding currents of 120 amperes AC, and under test conditions as described above, both of these samples produced weld deposits superior to those produced by unsheathed electrodes of the same diameters.

Weld deposits made on cast iron plates with sheathed and unsheathed electrodes of this general type have been examined by transversely fracturing the test plates across the weld deposits. By such examination it is evident that although the weld bead deposited

with a sheathed electrode has a lower profile than that deposited by an unsheathed electrode operating under the same conditions, the penetration of the weld into the substrate metal is greater in depth and extent with the sheathed electrode.

Example 8.

The electrode type selected was similar to that of Example 6 except that the core wire had a diameter of 3/32". Sample electrodes were sheathed by dipping in a medium comprising 10 grams of aluminum flake particles suspended in a solution of 5 grams of diammonium phosphate in 30 grams of water to apply a layer which became approximately .005" thick when dry, followed by air drying, baking for 12 hours at 250°C to bond the inorganic matrix, then applying a thin overlayer of copper bronze flake in acrylic matrix by spraying to stabilize the reflective sheath as described in Example 5 and illustrated in Fig. 11 of the drawings. Welding tests were made using 85 amperes AC welding current to deposit horizontal stringer beads on cast iron plates. Sheathed test electrodes produced excellent flat beads with good wetting of the substrate. Electrodes maintained arc drive to complete consumption of the electrode in welding even though the rods became visibly bright red under passage of the relatively high welding current through the small diameter, highly-resistive core material. Weld beads exhibited no porosity. Under similar conditions, unsheathed electrodes produced beads with higher crown and lesser wetting of the substrate and, owing to high operating temperatures, such electrodes generally lost arc drive abruptly well before the electrode was completely consumed.

Example 9.

The electrode type selected for test was a chrome-nickel-iron alloy core wire of 3/32" diameter coated with a primary flux coating comprising inorganic oxides in a silicate binder matrix. Sample rods were sheathed by dipping in a slurry of aluminum flake particles in silicon-modified alkyd resin similar to that described in Example 1, followed by air drying. The particular purpose of this test was to determine the effect of the sheathing on arc strikeability under difficult welding conditions. The substrate used was mild steel plate 3/16" thick, and the welding current was set at 80 amperes AC. The test comprised striking an arc, drawing a horizontal stringer bead on the substrate plate for 2 seconds, breaking the arc completely for 2 seconds, then restriking and holding for 2 seconds, and so forth in like manner for a total of 20 strikes. Under the relatively unfavourable conditions of low amperage alternating current in this test, it was found difficult to strike and maintain stable welding arcs with unsheathed elec-

trodes which sporadically missed initiation of arcing on striking. Under the same conditions, the sheathed electrodes were definitely superior, and consistently initiated stable arc on every strike.

Example 10.

The electrode type selected for test and the sheathing composition were similar to those used in Example 9, except that the core wire diameter was 1/16". Comparative welding tests were made of sheathed and unsheathed electrodes of this type by depositing horizontal stringer beads on thin, mild steel plates 3/32" thick using a welding current of 40 amperes DC reverse polarity. It was noted that the thin substrate plate became much hotter when welds were made with a sheathed electrode as compared to welding with an unsheathed electrode. Performance of the unsheathed electrode was marginal at this low current, giving a high-crowned, poorly-wetting bead with a dark, oxidized surface. The sheathed electrode under the same conditions gave a satisfactory bead, flat and with good wetting of the substrate and, after slag removal, the bead produced by the sheathed electrode was bright and shiny.

Example 11.

The electrode selected for test comprised a 3/32" diameter core wire of a ferrous composition of the type known generally as "high-speed" tool steel alloy, said core being coated with a primary layer of conventional inorganic fluxing and deoxidizing materials. Samples were sheathed as in Example 1. Weld performance testing comprising the deposition of a single stringer bead along the edge of a steel plate 3/16" thick using a welding current of 70 amperes direct current, reverse polarity. As compared to an unsheathed electrode under the same conditions, a sheathed electrode gave better wetting and a flatter weld deposit.

Example 12.

The electrode type selected for test comprised hard metal carbides enclosed in a tubular mild steel container or envelope, the composite being coated externally with a primary flux layer of inorganic oxides. Samples of this type of electrode were sheathed with an energy-reflective film .002" thick comprising about 30% by volume of aluminum flake particles in a matrix of silicone-modified alkyd resin applied according to the technique described in Example 1. Comparative tests were made of sheathed and unsheathed electrodes using a welding current of 160 amperes DC reverse polarity to deposit horizontal weld beads on the edge of mild steel plate 3/16" thick so as to simulate the hard-facing of cutting tool edges. Under these conditions, the sheathed electrode gave a more stable arc,

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better control of the weld deposition operation, and a noticeably flatter, better-wetting bead on the edge of the steel plate than did the unsheathed electrode.

5 Example 13.

10 The electrode type selected for test comprised an aluminum core wire $\frac{1}{8}$ " in diameter coated with a primary flux layer of inorganic halides and oxides. Sample electrodes were
15 sheathed with an energy-reflective layer by wiping the surface of the flux layer with a paste of rolled aluminum flake powder of the so-called standard lining grade in a medium of 30% by weight of mineral spirits. Following
20 air drying to evaporate the mineral spirits, the resulting sheath comprised an overlay of .0005" of mechanically adherent aluminum flake particles. Welding tests were made by depositing horizontal stringer beads on aluminum sheet $\frac{1}{4}$ " thick using welding current of 95 amperes direct current reverse polarity. Under these conditions, an electrode with the wiped-on reflective layer produced a weld bead that was noticeably flatter and with
25 better wetting of the substrate plate than did an unsheathed electrode of the same type.

 Example 14.

30 The electrode type selected for test was similar to that of Example 13. Sample electrodes were provided with energy-reflective sheathing according to the method described in Example 5 except that electrodes to be coated first were wet with water before the sheath composition was brushed onto the
35 primary flux layer. Sheathed electrodes were air dried, heated 48 hours at 120°C then 1 hour at 220°C. Welding tests were made using a welding current of 85 amperes DC reverse polarity to deposit horizontal stringer beads on $\frac{1}{4}$ " thick aluminum substrate plates. Under these conditions, the sheathed electrodes gave much flatter, better-wetting beads with noticeable improvement in substrate penetration by the weld deposit. In addition, the
40 sheathed electrodes gave smoother running arc with better arc and weld control as compared to untreated control electrode.

 Example 15.

50 The electrode type selected for test comprised a $\frac{1}{8}$ " diameter copper-base alloy core surrounded by a primary flux coating of inorganic constituents. Samples were sheathed with a reflective film of aluminum using the materials and method described in Example 1.
55 Braze welding tests were made using a current of 120 amperes AC to braze weld steel shims and brass shims to a mild steel substrate plate with a continuous pass, horizontal fillet weld. As compared to a conventional unsheathed
60 electrode, a sheathed electrode gave a somewhat hotter arc and a better wetting of the substrate and shim metals by the weld deposit.

Similar results in favor of the sheathed electrode were noted in a similar test made using a welding current of 120 amperes DC reverse polarity.

 Example 16.

70 The electrode type selected for test was similar to that of Example 9 except that core wire diameter was $\frac{1}{8}$ ". Sample electrodes were provided with an energy-reflective sheath by applying two light coatings of copper bronze flake particles in acrylic resin binder according to the method described in Example 5, allowing a sufficient period for drying between
75 sprayings. Total thickness of sheath was .0004". Welding tests were made by depositing horizontal stringer beads on mild steel plates $\frac{3}{16}$ " thick using a current of approximately 105 amperes AC. Whereas at this current level, the arc voltage of an unsheathed control electrode averaged approximately 21 volts the arc voltage of a sheathed electrode averaged about 10% higher. In addition, the sheathed electrode provided a smoother,
80 quieter arc with less weld spatter, and the resulting weld bead exhibited evidence of better wetting of the substrate metal by the deposited weld metal. In addition, the bead deposited by the sheathed electrode appeared
90 smoother with less ripple.

 Example 17.

95 The electrode type selected for test was similar to that of Example 16. Samples were provided with a reflective sheath of aluminum flake particles in organic binder according to the method and materials described in Example 1 except that, by thinning the medium with solvent, the thickness of the resulting sheath was reduced to approximately
100 .0009". Following this, a second overlayer of copper bronze pigment in acrylic matrix was provided by spraying followed by air drying as described in Example 5. The thickness of the overlay film was .0003". Samples of unsheathed and sheathed electrodes were weighed, then placed in an enclosed humidity chamber and held for a period of 40 hours at a relative humidity of 100% at a temperature of 70°F. During this exposure, the unsheathed electrodes absorbed a quantity of water into the flux coating equivalent to 5.1 grams of water per pound of electrodes whereas the sheathed electrodes absorbed less than 0.2 grams of moisture per pound of electrodes. Further, whereas the slight amount of moisture absorbed by the sheathed electrodes was loosely held and was readily removed by heating at 150°F for an hour, the moisture absorbed by the unsheathed electrodes was more tightly held and its removal required an extended time at temperatures about 400°F. Fig. 12 depicts the relative absorption of moisture by conventional and sheathed electrodes as a function of time.

Example 18.

The electrode type selected was similar to that of Example 6 except that the diameter of the nickel-alloy core wire was $\frac{1}{8}$ ". Sample electrodes were sheathed by dipping into a suitable mixture of aluminum flake pigment and silicone-modified alkyd resin binder in organic solvent to leave, after drying, a reflective sheath .001" in thickness comprising 33% by volume of metallic aluminum. Welding tests were conducted by depositing pairs of horizontal stringer beads on cast iron plates $\frac{3}{8}$ " thick using welding currents of 85 amperes AC for one bead and 120 amperes AC for the other. Separate substrate plates were used for deposition of the test beads from sheathed electrodes and from conventional unsheathed electrodes. At either current level, the sheathed electrodes provided flatter beads exhibiting better wetting of the substrate and with greater depth of penetration thereof. Fig. 5 is a cross-sectional view of the test beads deposited by the unsheathed electrode at the two different current levels, while Fig. 6 is a similar view of the test beads produced under the same conditions by the electrodes sheathed according to the invention. In both cases, the smaller bead was deposited at 85 amperes AC, the larger bead at 120 amperes AC.

Example 19.

The electrode selected for test was similar to that of Example 13. Samples were coated with a mixture of aluminum flake in polyurethane resin matrix prepared by mixing 48 grams of base resin in a solvent marketed by the Sherwin-Williams Company under the trade name Polane, 8 grams of isocyanate catalyst, 16 grams of additional solvent thinner, and 30 grams of a paste of aluminum flake pigment in mineral spirits comprising 75% by weight of aluminum. This mixture was wiped onto the test electrode to leave a sheath which, when allowed to dry and polymerize, had a thickness of .002". Welding tests were made by depositing horizontal stringer beads on aluminum substrate plates $\frac{1}{4}$ " thick at a current of 90 amperes DC reverse polarity (electrode positive). A cross-section of the bead deposited by the conventional unsheathed electrode under these conditions is shown in Fig. 7. The bead deposited by the sheathed electrode under the same conditions is shown in Fig. 8. As will be apparent from these microphotographs, the electrode sheathed according to the invention produced a weld deposit noticeably flatter and with better wetting of the substrate as evidenced by the relatively low contact angle between the edge of the weld deposit and the substrate plate in Fig. 8.

Example 20.

The electrode selected for test was repre-

sentative of the type known as "low hydrogen" commonly used for high-performance welding in critical applications, and comprising a ferrous metal core wire $\frac{3}{32}$ " in diameter coated with a primary layer of inorganic fluxing and deoxidizing materials. Sample electrodes were sheathed by dipping into a mixture of aluminum flake pigment and silicone-modified alkyd resin in a solvent medium followed by drying in air. The resulting reflective sheath comprised 33% by volume of aluminum flake in a .001" layer circumferential and adherent to the primary flux coating. Comparative tests of welding performance were made by depositing weld beads by the so-called "vertical up" technique in the interstices between adjacent steel plates $\frac{3}{16}$ " thick held at right angles to each other using a welding current of 115 amperes AC. Fig. 9 is a photograph of the weld bead deposited by the unsheathed electrode under these conditions, while Fig. 10 is a photograph of the weld bead deposited under the same conditions by an electrode sheathed as described above. It will be apparent that the electrode sheathed according to the invention produced a flatter, more adherent weld deposit than the unsheathed electrode.

In addition to the various techniques of dipping, brushing, spraying, wiping on, wrapping or casting the sheath onto the electrode, there are sheath compositions which can be applied by dry powder fluidized bed or electrostatic spraying application, or more exotic techniques such as electroplating or vacuum evaporation-condensation and the like. The invention is not limited to any particular method of applying the sheath to the welding electrode, although it is expected that the simpler and less costly techniques of dipping, spraying and the like will most frequently be utilized. It will be understood that, at the time the sheath is applied, the electrode should ordinarily be moisture-free insofar as practicable.

In the representative electrode examples set forth above, the energy-reflective sheathing is in all instances metal-based or metal-bearing and has the additional common characteristic of the metal being disposed as an effective continuum regardless of the method of applying the sheath to the electrode. In fact, this latter characteristic is salient to the invention and establishes the ultimate lower limit for the metal content of the sheath, other factors being preliminary ignored. In other words, whatever other requirements may dictate as to the metal content of the sheath, it is necessary that the metal content be sufficient and of such nature and disposition as to establish the sheath as an effective reflective continuum around the usable length of the electrode. The other requirements may lead to an increased metal content or volume, but not to a significantly lower one. The improved performance of the sheathed welding electrode

is in great part the result of the energy reflectivity of the metal continuum of the sheath, therefore such continuum must be substantially maintained to obtain the advantages of the invention. Although this description has emphasized the use of metallic sheathing, it will be apparent to those skilled in the art that substances other than metals could be utilized for the sheath provided that such substances have or can be applied in a manner to have a substantial energy-reflectivity characteristic. Examples of such non-metallic sheathing materials or substances are heat-stable inorganic or ceramic compositions applied in a form which provides an adequate degree of specular reflection.

In some applications, such as where the electrode is used at relatively high arc temperatures, the selected metal of the sheath may be a relatively low-melting metal, such as aluminum, which will be vaporized or dissipated during the welding operation without significantly entering into or contaminating the filler metal deposited by the electrode core 11. Examples of such a sheath are, inter alia, described in Example Nos. 1, 6, 9, 11 and 12 above. In other applications, the metal for the sheath 14 may be selected to contribute some desirable property to the filler metal or to be similar in whole or in part thereto, as in Examples Nos. 3 and 13 above. Some of the sheath metals which have been utilized are aluminum, stainless steel, copper-bronze, and combinations thereof. It will be recognized by those skilled in the art that certain metals which otherwise might be used to provide the energy-reflective sheath, such as cadmium or beryllium for example, are not practicable for such purpose because of the toxicity of the metals and their vapors.

Suitable vehicles in the form of liquids, slurries, pastes and the like are indicated in the examples listed above. Organic resins appear to be the most suitable, although inorganic binder compositions have also been successfully utilized, as in Example Nos. 5 and 14. These sheathings have an additional advantage in reinforcing and protecting the underlying primary flux coating which often is a brittle composition which is easily damaged in handling and in shipping.

It has been found that an additional reflective film or very thin layer, from .0001 to .0005" thick applied over the basic sheath composition in the form of an overspray, as in Example Nos. 5, 8 and 17, may serve to effectively further improve the performance of the welding electrode after lengthy periods of storage and particularly at higher operating current values at which the electrodes attain red heat in operation. This overlayer or stabilizing film 15, illustrated in Fig. 11 of the drawings, further maintains the integrity of the underlying first reflective sheath, as well as enhancing the maintenance of arc drive. In

fact, a multiplicity of thin layers of reflective overlay 14 will, for an equivalent total sheath thickness, be more effective than a single thick layer owing to such factors as promotion of reflectivity through a higher degree of flake pigment leafing and decreased thermal conductance. In addition, a sheath carrying a plurality of very thin layers may, under certain conditions, be a more effective barrier to moisture absorption by the electrode.

It will be understood that, as applied to mechanically adherent sheath compositions, such as that of Example No. 13, the overlayer need not necessarily be reflective per se or contain or comprise metal to serve effectively as a reinforcement for the underlying reflective sheath, but can be a protective film such as, for example, an acrylic resin or the like. This protective function is accomplished by the binder or matrix in sheath compositions such as those of Example Nos. 1, 5 and 6. Further, binder-reinforced metallic particle sheaths or continuous film metallic sheaths, regardless of how applied, serve to maintain useful arc or weld deposit modifying components within the primary flux coating by preventing or minimizing loss, such as by evaporation or oxidation, of such valuable flux layer components during high-temperature operation of the electrode. Thus, an additional advantage of the invention is that it enables the retention of useful and desirable modifiers in flux layer compositions, which are not possible or feasible with conventional electrode coating processes and materials.

Figs. 3 and 4, previously referred to in Example 1, are comparative photomicrographs of the cross-section of an arc welded butt joint of mild steel sheets 3/32" thick. Fig. 3 shows the joint obtained using a horizontal weld pass at an operation current of 45 amperes AC using a 1/16" diameter commercial mild steel electrode having an inorganic flux coating. Fig. 4 shows the butt joint obtained on the same substrate sheet and under the same operating conditions using the same commercial electrode modified by the addition of a sheath approximately .002" thick comprising aluminum flake particles in a binder of silicone-modified alkyd resin as described in Example No. 1. It will be noted in comparing Figs. 3 and 4 that in the joint obtained by use of the metal sheathed electrode, the filler metal bead is much flatter and wider than in Fig. 3. Also that penetration of the joint is much greater in Fig. 4 than in Fig. 3. This results from the energy-reflective characteristic of the metal continuum of the sheath which produces significantly increased arc drive, improved arc stability, higher arc voltage and temperature at a given operating current value, and the maintenance of uniformity in the characteristics of the arc as the electrode is consumed. Better wetting action and penetration are achieved, as indi-

cated in the photomicrographs.

Also of importance, as indicated in Example 17, is the fact that the metal continuum of the sheath 14 substantially lengthens the shelf life of the electrode by minimizing the absorption of moisture by the primary flux coating with its consequent degradation of electrode performance and weld deposit quality.

In the graph of Fig. 12, comparative moisture absorption of like sheathed and unsheathed electrodes is illustrated by plotting the percentage by weight of water or moisture absorbed by the electrode flux coating against the number of hours of exposure of the electrode to 100% humidity at 65°F. The test results for the unsheathed electrode are shown by the curve indicated by the reference numeral 16 and the test results for the sheathed electrode are shown by the curve indicated by the reference numeral 17. The dramatic difference in moisture absorption between the sheathed and unsheathed electrodes is evident and is translated into minimal deterioration of performance for the sheathed electrode as well as substantially longer shelf life.

Although the improved shelf life obtained from sheathed electrodes is a significant advantage, the primary attribute of the sheathed electrode is its characteristic of energy-reflectivity. The metal or other energy-reflective component of the sheath is in a form or configuration which presents interiorly-directed surfaces toward the core of the electrode. These surfaces serve to reflect or direct back toward the core and its point of arc attachment, radiant energy which would otherwise radiate from the rod in a manner known to the art. This loss of energy, both by radiation and convection, occurs throughout the length of the electrode with a major portion of the loss occurring at the point of arc attachment. The specular effect of the sheath results in a containment of energy in the electrode, which would otherwise be lost and unavailable for use in the welding process. Thereby, the sheathed electrode in effect increases the available welding energy with a consequent higher core temperature which, in turn, increases the electrical resistance of the core and results in a greater I²R heating effect and a higher level of energy in the arc itself.

The improved heating effect increases the rate of melt of the core at the point of arc attachment which is believed to result in a more pronounced cup effect at the arc end of the electrode. This cup effect may be further enhanced by the mechanical reinforcement of the flux coating by the sheath at the arc end of the electrode. The deeper or more pronounced cup immediately surrounding the arc end of the electrode provides an additional containment against energy losses at this critical terminal portion of the rod.

The consequence of this containment and concentration of available energy in the elec-

trode is a higher energy level in the arc itself, a greater concentration and direction of the arc stream, a significant increase in arc voltage drop at a given welding current level, as discussed in Example 16, with higher arc temperature and greater arc drive, and improved penetration of the substrate.

There is also reason to believe that with certain types of electrodes, the sheath 14 promotes improved spray transfer of filler metal from the core to the substrate, thus affording better control of the arc and the deposition of the weld metal, particularly in difficult welding situations in which the less desirable globular transfer mechanism may interfere with arc control and weld deposit quality.

WHAT WE CLAIM IS:—

1. A consumable arc-welding electrode, comprising, in combination, a consumable metal core, a modifier-containing coating on said core, and an adjacent sheath providing an energy-reflective continuum substantially surrounding said coating.

2. A consumable arc-welding electrode, comprising, in combination, a consumable electro-conductive metal core, a primary coating on said core, and an adjacent sheath providing an energy-reflective continuum substantially surrounding said primary coating.

3. A consumable arc-welding electrode, comprising, in combination, a consumable electro-conductive metal core, modifier-containing primary coating adherent to said core, and a sheath adjacent to said primary coating and providing an energy-reflective continuum substantially surrounding said primary coating.

4. An electrode as claimed in claim 1, including an overlay of an energy-reflective film provided on said sheath.

5. An electrode as claimed in claim 1, including an overlay of a protective coating provided on said sheath.

6. An electrode as claimed in claim 1, wherein said energy-reflective continuum comprises reflective metal.

7. An electrode as claimed in claim 3, wherein said continuum comprises a substantially continuous metallic layer.

8. An electrode as claimed in claim 7, wherein said layer is in foil form.

9. An electrode as claimed in claim 7, wherein said metallic layer is in cast form.

10. An electrode as claimed in claim 7, wherein said metallic layer is in particle form.

11. An electrode as claimed in claim 7, wherein said metallic layer comprises metal particles in a binder matrix.

12. An electrode as claimed in claim 7, wherein said sheath has a thickness of at least 0.0001 inches.

13. An electrode as claimed in claim 7, wherein said sheath has a thickness of at least

- 0.0001 inches and not more than 0.005 inches.
14. An electrode as claimed in claim 13, wherein said sheath has a thickness of at least 0.0005 inches and not more than 0.003 inches.
15. An electrode as claimed in claim 11, wherein said metallic layer comprises at least 5% by volume of the sheath.
16. An electrode as claimed in claim 7, wherein said metallic layer is adherent to said primary coating.
17. An electrode as claimed in claim 11, wherein said metal particles are contiguous to each other.
18. An electrode as claimed in claim 11, wherein said matrix is of organic composition.
19. An electrode as claimed in claim 11, wherein said matrix is of inorganic composition.
20. An electrode as claimed in claim 6, wherein said reflective metal of said continuum is the same as that of the core.
21. An electrode as claimed in claim 6, wherein said reflective metal of said continuum is dissimilar to that of the core.
22. An electrode as claimed in claim 10, wherein said particles are of ferrous metal.
23. An electrode as claimed in claim 10, wherein said particles are of non-ferrous metal.
24. An electrode as claimed in claim 10, wherein said particles are a mixture of different metals.
25. An electrode as claimed in claim 23, wherein said particles are aluminum.
26. An electrode as claimed in claim 7, including an overlay on said sheath of an energy-reflective film comprising a substantially continuous metallic layer.
27. An electrode as claimed in claim 26, wherein the thickness of said film is less than the thickness of said sheath.
28. An electrode as claimed in claim 26, wherein the metal of said film is dissimilar to the metal of said sheath.
29. A consumable arc-welding electrode substantially as hereinbefore described with reference to and as illustrated in Figs. 1, 2 and 11 of the accompanying drawings.
30. A consumable arc-welding electrode as claimed in any preceding claim, substantially as hereinbefore described and exemplified.

POTTS, KERR, & CO.,
27, Sheet Street,
Windsor,
Berkshire.

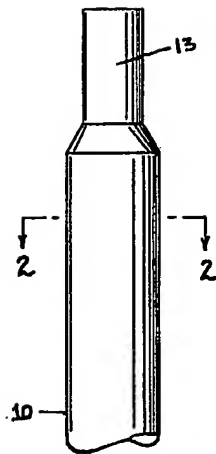


FIG. 1

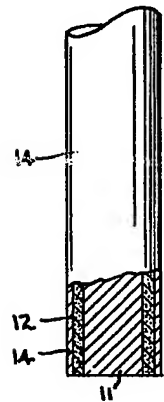


FIG. 2

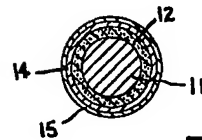


FIG. 11

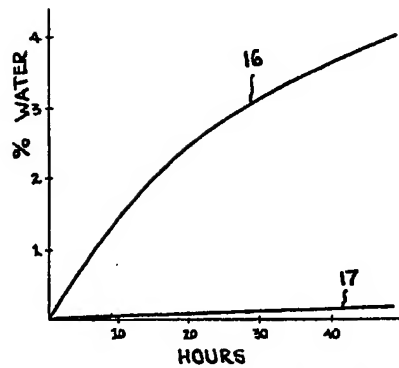


FIG. 12

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5 SHEETS

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Sheet 2



FIG. 3



FIG. 4

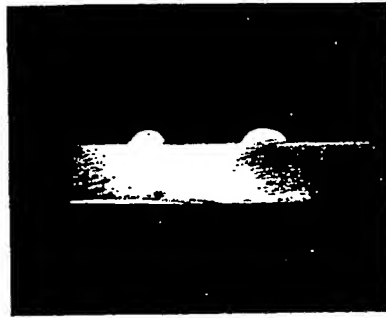


FIG. 5

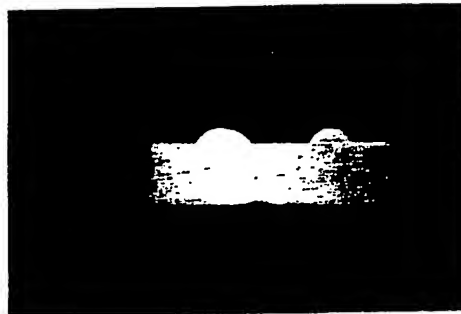


FIG. 6

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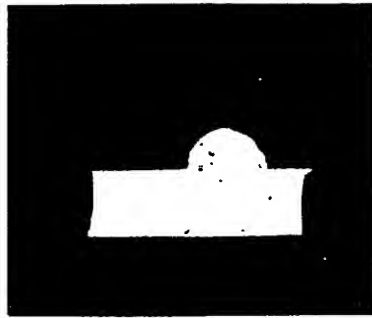


FIG. 7

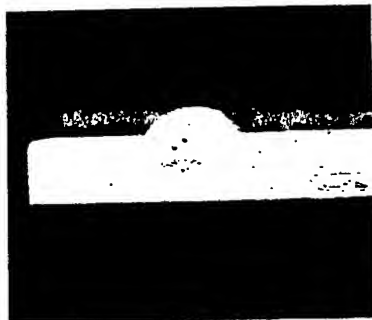


FIG. 8

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FIG. 9



FIG. 10